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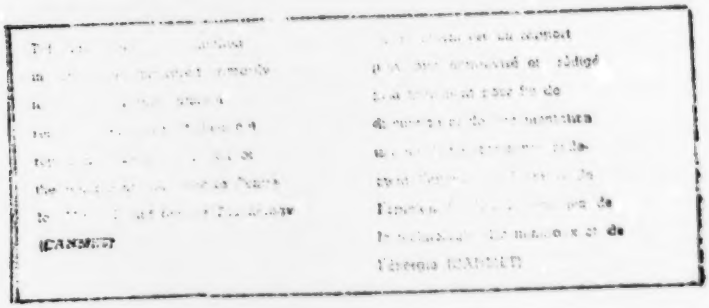
TRACER GAS USED FOR THE MINE FIRE SIMULATIONS

G.W. Klinowski and D.J. Kennedy

Division Report CRL 89-87(TR)
November 1989



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TRACER GAS USED FOR THE MINE FIRE SIMULATIONS

by

G.W. Klinowski* and D.J. Kennedy**

ABSTRACT

Portable tracer gas equipment was recently used to simulate an underground coal mine fire.

Sources of fire contaminants simulated by tracer gas were located in the main air intakes. Air samples from strategic locations within the mine were collected and analysed for the SF_6 content. The time-related smoke contamination patterns were detected and the assumption of the integrity of smoke-free escape roadways fully proven. Portability and reliability of the testing equipment was also asserted.

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UTILISATION DE GAZ TRACEURS DANS LA SIMULATION DES INCENDIES DANS LES MINES

par

G.W. Klinowski* et D.J. Kennedy**

RÉSUMÉ

Du matériel portatif de détection par gaz traceur a été utilisé récemment pour simuler un incendie dans une mine de charbon souterraine.

Des sources de contaminants associés aux incendies et simulés par un gaz traceur ont été localisées dans la prise d'air principale. Des échantillons d'air prélevés à des endroits stratégiques dans la mine ont été soumis au dosage du SF_6. Les voies de contamination dans le temps par la fumée ont été établies, et l'hypothèse de l'intégrité de voies d'évacuation exemptes de fumée a été nettement démontrée. La portabilité et la fiabilité du matériel d'essai ont aussi été vérifiées.

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INTRODUCTION

Over the past seven years the Cape Breton Coal Research Laboratory's staff has designed, built, tested and proved the necessary hardware, software and methodology of tracer gas based surveying techniques applied in the field of mine ventilation.

Tracer gas based techniques were used in a broad range of applications where traditional ventilation methods do not provide the required accuracies or cannot be employed effectively.

During this type of volume survey, a small and precisely regulated stream of tracer gas, liberated from the pressure bottle, is mixed thoroughly with the turbulent airstream. Air samples taken downstream from the point of gas release are chromatographically analysed to determine the concentration of tracer gas in the sampled location. The airflow volume within the sampled location is calculated from the known tracer gas release rate and the detected concentration in the samples; measuring errors usually remain within ±5% margins.

When tracer gas is released at a steady rate and air samples are collected from selected roadways within the ventilation network, the airflows distribution patterns and their mixing rates can be calculated from the tracer gas concentration at the release point and from the concentrations in sampled locations. This method was recently used during a joint USBM/CANMET survey in Cyprus Orchard Valley Mine to detect time-related smoke contamination levels within the mine during asimulated mine fire.

OBJECT OF SURVEYS

As previously stated, tracer gas based ventilation techniques can be and were used in many problematic situations where the standard ventilation methods are inadequate. One such problem, faced by many mine operators, is the emergency imposed by the ever present threat of a mine fire.

An understanding of the progress of smoke contamination zone and the demonstrated integrity of appointed escape routes can save lives and

property during the fire. That knowledge can be gained quickly and inexpensively by the application of tracer gas based fire simulation methods.

During the fire simulation exercise, tracer gas release systems emulating the fire are positioned in sensitive locations within the mine. The tracer gas concentrations in air samples collected in strategic points of the mine indicate their "contamination" levels at any given time.

Simulations undertaken at the Orchard Valley Mine were planned to assert the integrity of so called "smoke-free" roadway and to gain knowledge of the smoke distribution patterns in the event of fires erupting in two different locations within the mine.

Testing of the performance, portability and flexibility of the equipment was an additional, important purpose of these surveys.

MINE LAYOUT AND VENTILATION

A schematic mine layout, presented in Figure 1, is typical for room and pillar extraction method. All three portal entries are the fresh air intake roadways: one is used by the diesel equipment, a belt conveyor is installed in the second, and the third is designated as a smoke-free entry to be used as an escape route during emergencies. The entries are connected every 100 ft by crosscuts; ventilation stoppings are erected in each crosscut.

Used air from the miner sections is conducted through the overcasts and along return entries towards the ventilation raise and the surface exhaust fan.

The mine ventilation network has been designed to provide maximum obtainable separation between intake roadways, especially between the belt and smoke-free entries. In case of fire in the belt or diesel roadway, a smoke-free entry should afford safe evacuation of the mine. This assumption was tested during the exercise which simulated a fire in the diesel and belt entries.

TEST EQUIPMENT

The continuous source of fire contaminants was simulated by the small pressure bottle containing liquid SF_6. The gas from the bottle passed through a pressure regulator to ensure a steady flow rate and was dispersed in the passing air, which carried it to the sampling locations.

About 100 m (300 ft) downstream from the release point, a series of air samples were taken from within the roadway profile to verify the completion of a mixing process. Original tracer gas concentrations were then defined.

With the tracer gas continuously released and dispersed in the airstream passing through the simulated fire source, groups of air samples were collected every few minutes from the tested sites; subsequent chromatographic analysis provided data on the presence and concentration of SF_6 in these locations.

The gas chromatograph output was then computer processed to produce tables and graphs documenting progressive effects of the simulated fire at each sampling point.

TEST #1

The fire was simulated in the belt entry, near the mine portals to create the widest "smoke" distribution pattern within the mine. Sampling locations (Figure 2) were close to the continuous miner section. All three intake entries (1 Left, Belt and 1 Right) were sampled every 5 minutes for 3 hours beginning with the tracer gas release. The object of the exercise was to define the time-related smoke contamination of the manned section in the event of the belt conveyor fire.

RESULTS OF TEST #1

Processed results of the chromatographic analysis of collected air samples are presented in Tables 1a to 1c.

The dilution factor was calculated by dividing the sampled SF_6 concentrations by the original tracer concentration at the release point.

As evident from Table 1a and Figure 2a, there would be no smoke at 1 Right entry for the first 1 hour from the fire outbreak. During next 60 minutes, the concentration of the toxic fire products in that location

would steadily rise to stabilize at about 3.3-3.5% of the source concentration.

Location 1 Left (Table 1b, Figure 2b) would remain essentially smoke-free for the first 70 minutes, after that time concentration of contaminants would stay at 0.2% (two parts per thousand) of the original level.

Belt entry, at crosscut #9, would be smoke-free for the first 50 minutes or so (Table 1c, Figure 2c), then smoke concentrations would rise rapidly to 35% of the fire levels.

TEST #2

This time "fire" broke out at the diesel entry, again close to the portals. Three distinct sampling zones were selected, all three intake entries were sampled within each zone. Diesel entry in each location, with its predicted high level of contamination, was sampled every 15 minutes; remaining belt entry and smoke-free entry every 5 minutes. Sampling locations are marked in Figure 3. The last group of samples were taken two hours after the tracer gas bottle was opened. This simulation was designed to test the integrity of the escape route along the smoke-free entry and the progress of smoke contamination within monitored locations.

RESULTS OF TEST #2

The assumption of the smoke-free escape route integrity was fully confirmed. Air samples collected in locations 1 and 2 along that entry did not contain any traces of SF_6 (Tables 2a and 2b); the detected concentrations of tracer gas at the smoke-free roadway, location 3 remained low (Table 2c, Figure 3a), reaching that location 80 minutes after gas was turned on. These results provide important and comforting assurance. In the case of a real fire breaking out in the diesel entry, men working at the continuous miner section could be safely evacuated since it takes only about 40 minutes to walk out to the surface.

As can be seen from the remaining Tables 3a to 3c and 4a to 4c and Figures 3b to 3g, both belt entry and diesel entry would fill with smoke in relatively short time; high concentrations of the dangerous fire product would be present in those entries in about 10 to 20 minutes from the fire's inception.

CONCLUSIONS

Objectives of both surveys were fully achieved. The assumption of the integrity of the smoke-free escape route was documented. Time related smoke contamination patterns of various portions of the mine were detected and these can be used as an important portion of the mine emergency plan.

Practicality and efficiency of the tracer gas based surveying techniques were fully proven; only several hours passed between the time of the samples collection and the presentation of results to the interested parties.

Testing of the portability, accuracy and reliability of the equipment was also very successful. All instruments performed very well and the estimated error of surveys was lesser than ±5%.

REFERENCES

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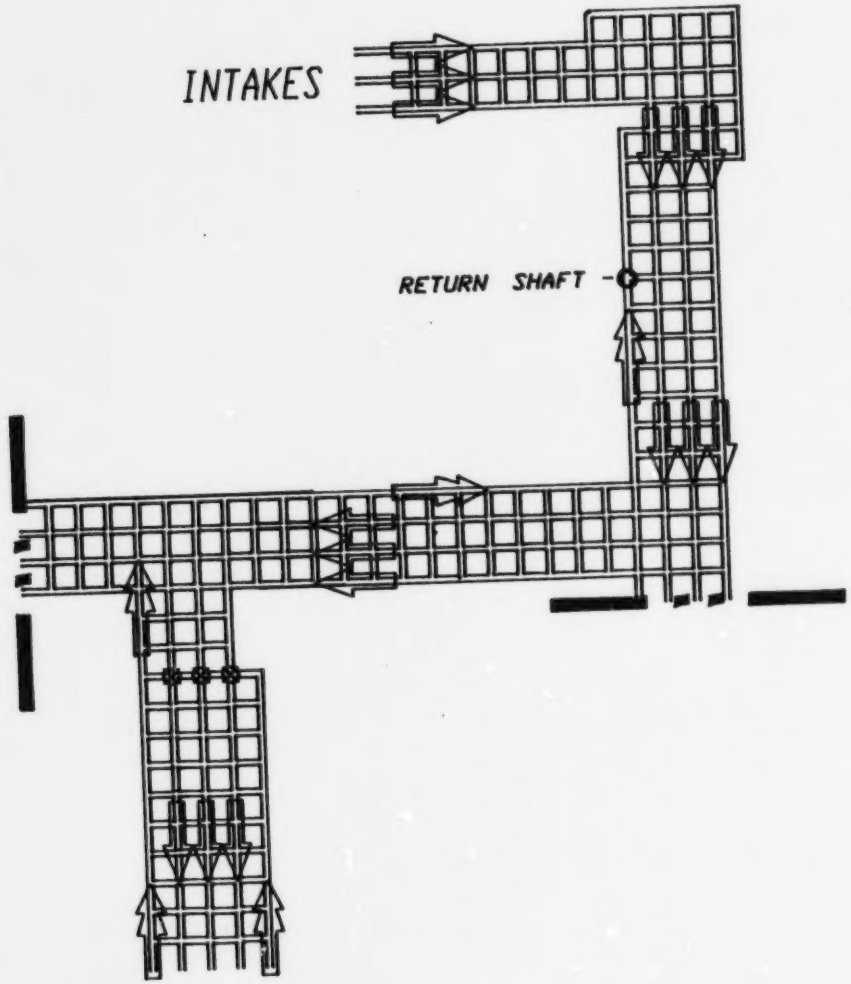

Figure 1 - Mine layout

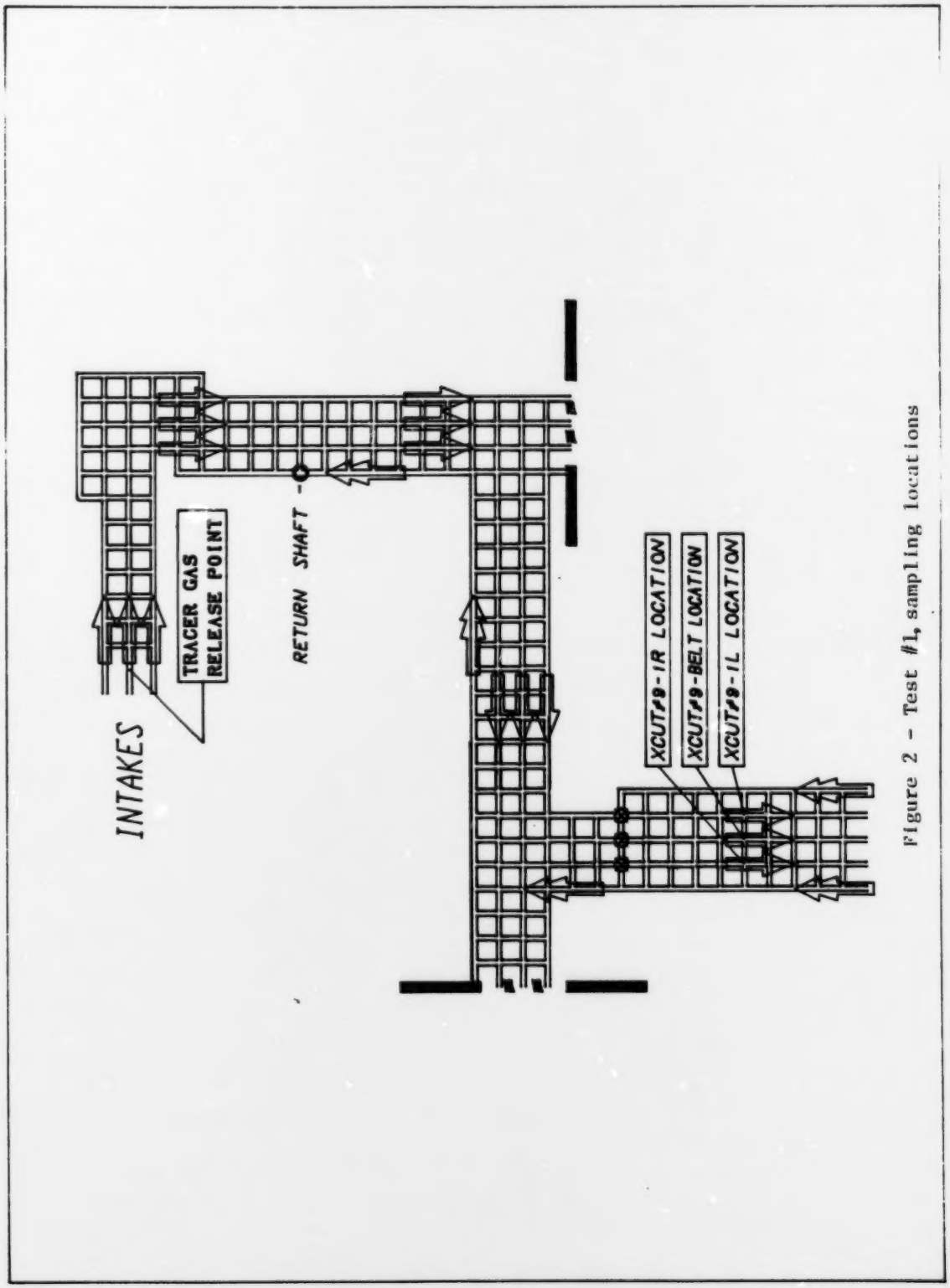

Figure 2 - Test #1, sampling locations

AMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	R210
2	0	0	R230
3	0	0	R300
4	0	0	R310
5	1.61	.003	R320
6	3.07	.007	R325
7	5.09	.012	R330
8	7.23	.017	R335
9	9.41	.022	R340
10	10.95	.026	R345
11	11.68	.028	R350
12	12.22	.029	R355
13	12.77	.031	R400
14	13.04	.031	R405
15	13.03	.031	R410
16	14	.033	R420
17	13.7	.033	R415
18	13.96	.033	R425
19	14.48	.035	R430
20	14.71	.035	R435
21	14.52	.035	R440
22	14.34	.034	R445
23	14.38	.034	R450
24	14.73	.035	R455
25	14.56	.035	R500
26	14.75	.035	R505
27	14.69	.035	R510

Table 1a - Test #1, location 1R

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	L315
2	0	0	L320
3	.51	.001	L330
4	.74	.001	L335
5	.91	.002	L340
6	.84	.002	L345
7	.82	.001	L355
8	.84	.002	L400
9	.86	.002	L405
10	.9399999999999999	.002	L410
11	.96	.002	L415
12	.91	.002	L420
13	.96	.002	L425
14	1.08	.002	L430
15	1.06	.002	L435
16	1.08	.002	L440
17	1.15	.002	L445
18	1.3	.003	L450
19	1.15	.002	L455
20	1.1	.002	L500
21	1.15	.002	L505
22	1.18	.002	L510

Table 1b - Test #1, location 1L

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	B210
2	0	0	B220
3	0	0	B225
4	0	0	B230
5	0	0	B235
6	0	0	B240
7	0	0	B245
8	0	0	B250
9	0	0	B255
10	0	0	B300
11	0	0	B305
12	0	0	B310
13	.77	.001	B315
14	10.79	.026	B320
15	39.66	.096	B325
16	71.47	.173	B330
17	96.52	.234	B335
18	116.61	.283	B340
19	121.2	.294	B345
20	129.03	.313	B350
21	132.14	.32	B355
22	134.25	.325	B400
23	133.65	.324	B405
24	132.44	.321	B410

Table 1c - Test #1, location belt

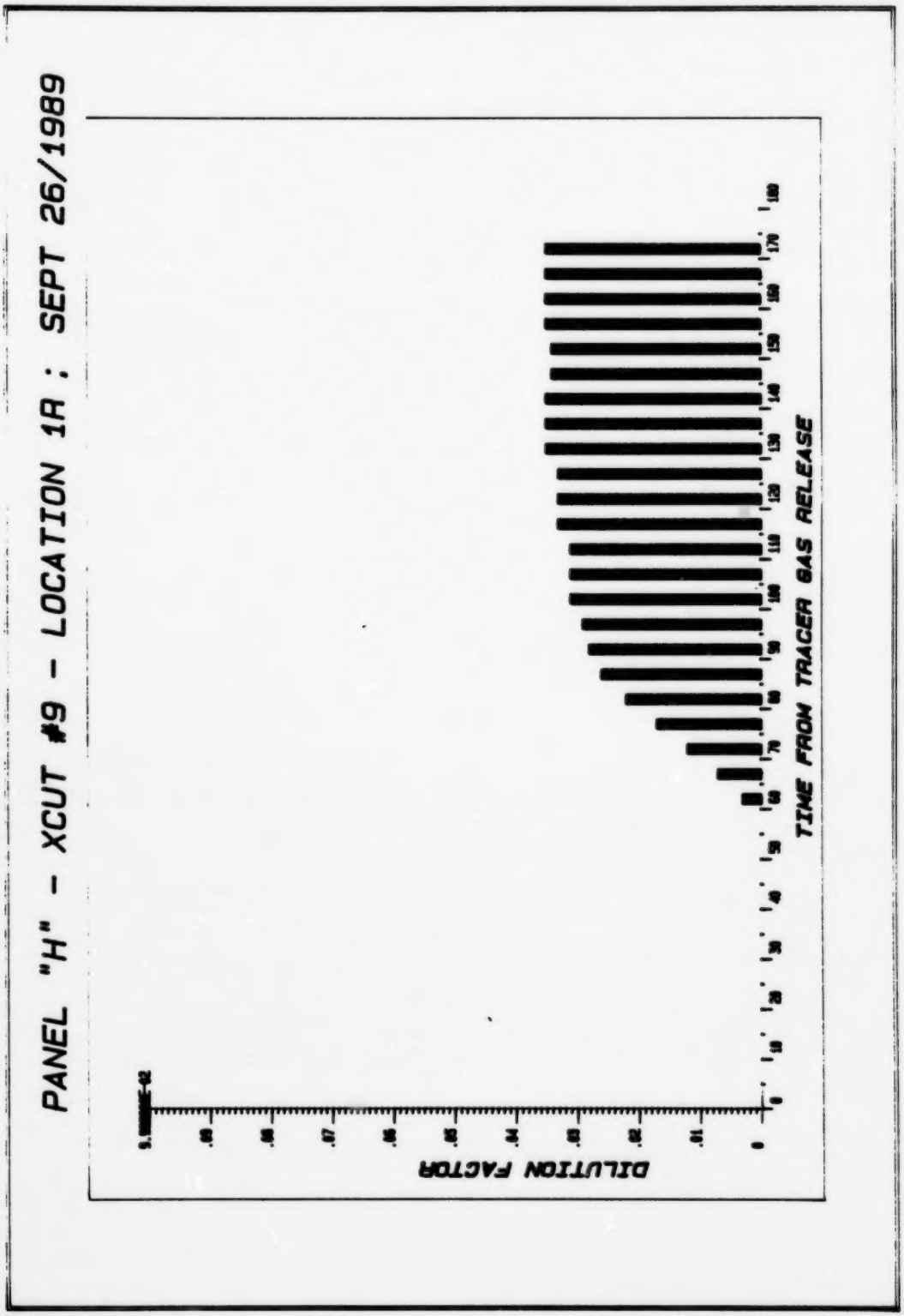

Figure 2a - Test #1, location 1R

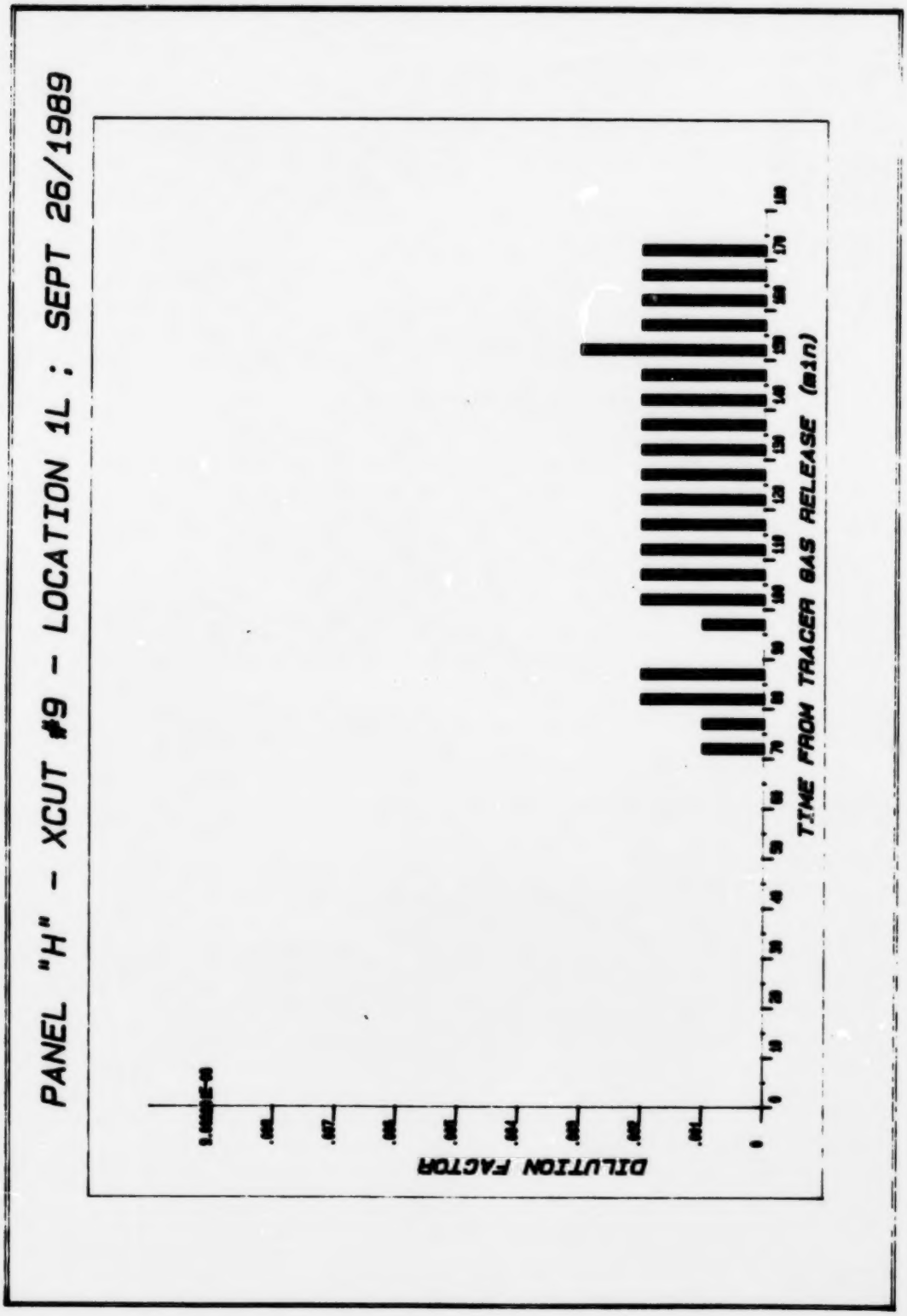

Figure 2b – Test #1, location 1L.

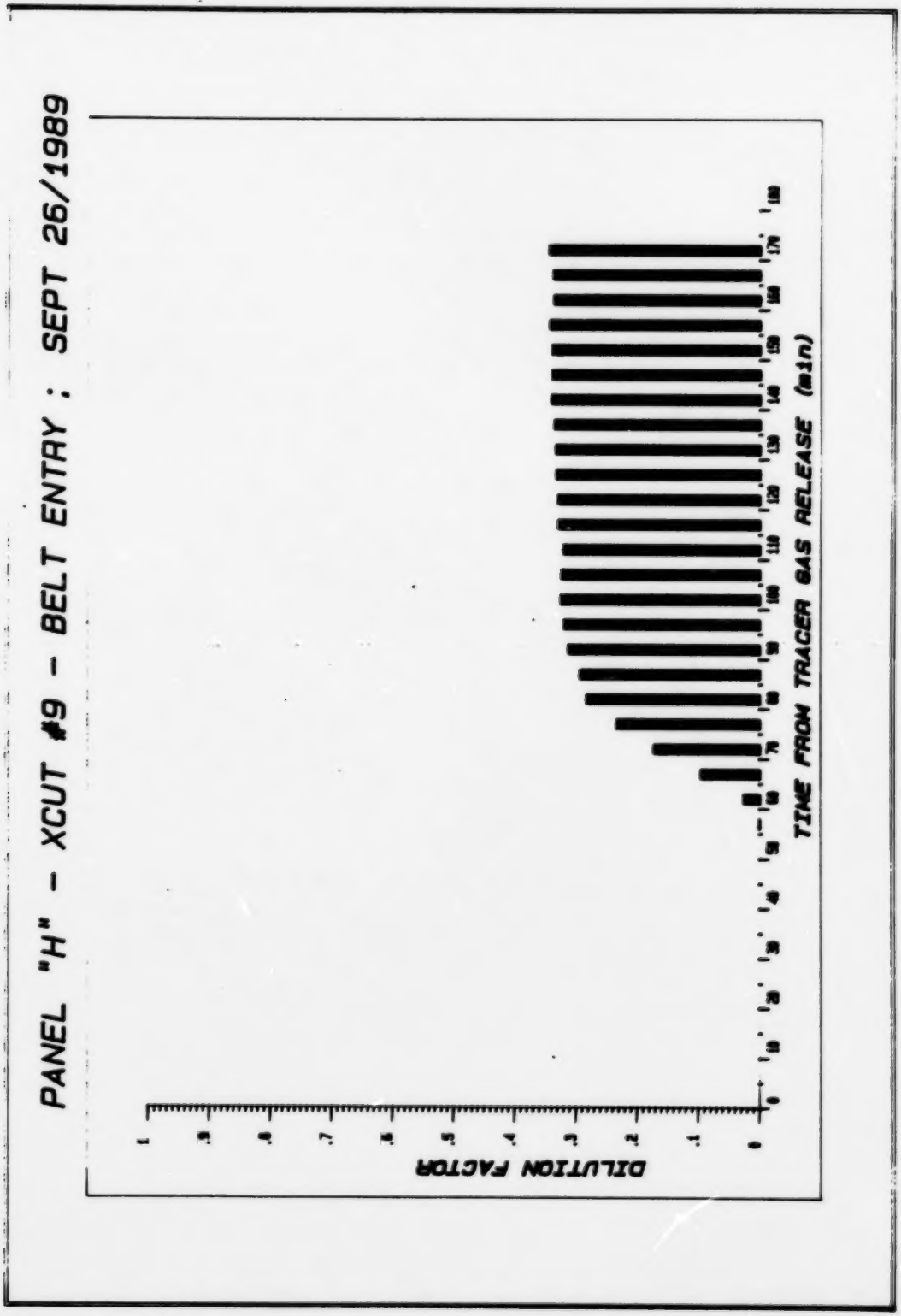

Figure 2c - Test #1, belt entry

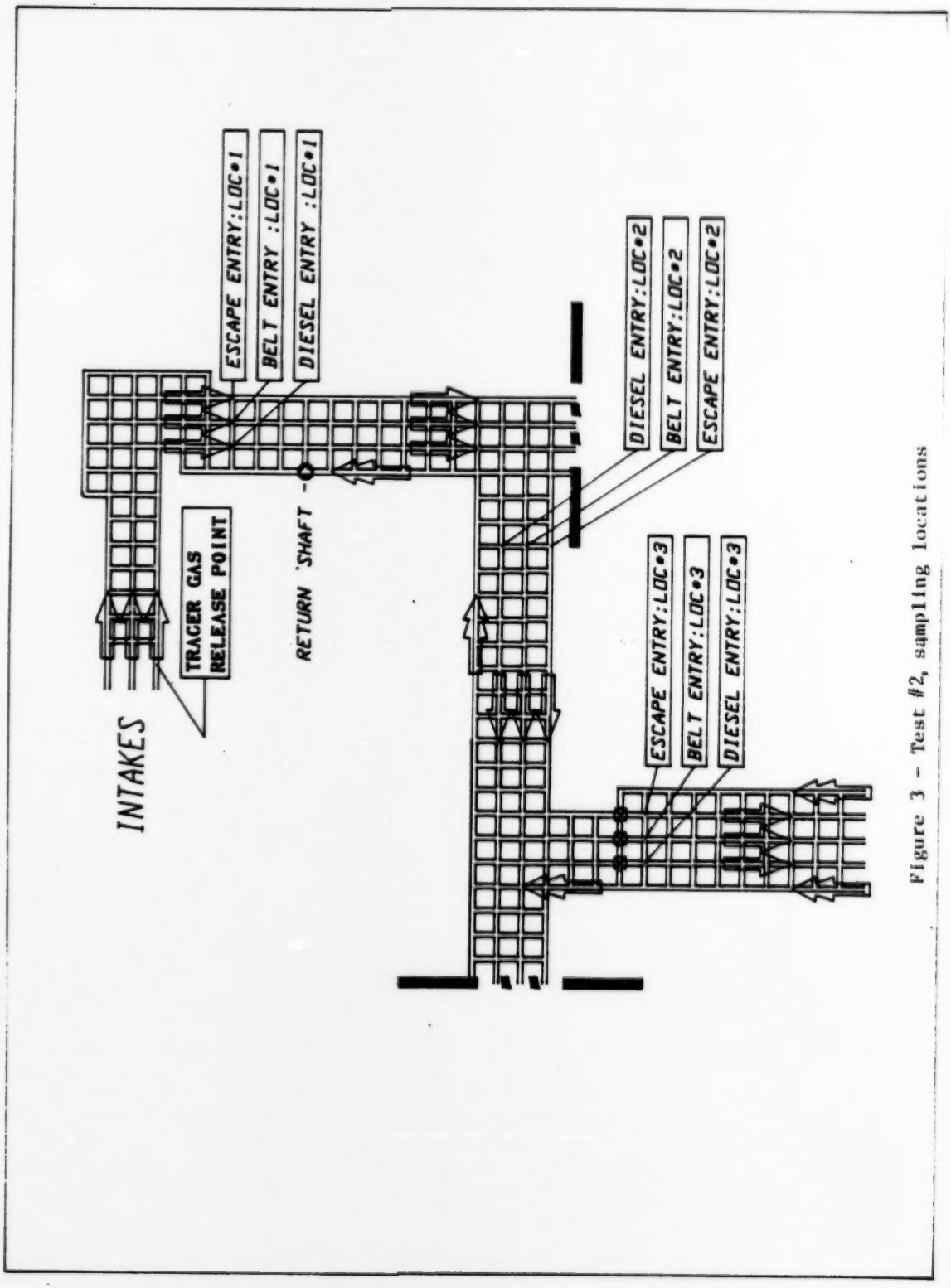

Figure 3 - Test #2, sampling locations

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	1SF900
2	0	0	1SF905
3	0	0	1SF910
4	0	0	1SF915
5	0	0	1SF920
6	0	0	1SF925
7	0	0	1SF930
8	0	0	1SF935
9	0	0	1SF940
10	0	0	1SF945
11	0	0	1SF950
12	0	0	1SF955
13	0	0	1SF1000
14	0	0	1SF1005
15	0	0	1SF1010
16	0	0	1SF1015
17	0	0	1SF1020
18	0	0	1SF1025
19	0	0	1SF1030
20	0	0	1SF1035
21	0	0	1SF1040
22	0	0	1SF1045
23	0	0	1SF1050
24	0	0	1SF1055
25	0	0	1SF1100

Table 2a - Test #2, location 1, smoke-free entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	2SF900
2	0	0	2SF905
3	0	0	2SF910
4	0	0	2SF915
5	0	0	2SF920
6	0	0	2SF925
7	0	0	2SF930
8	0	0	2SF935
9	0	0	2SF940
10	0	0	2SF945
11	0	0	2SF950
12	0	0	2SF955
13	0	0	2SF1000
14	0	0	2SF1005
15	0	0	2SF1010
16	0	0	2SF1015
17	0	0	2SF1020
18	0	0	2SF1025
19	0	0	2SF1030
20	0	0	2SF1035
21	0	0	2SF1040
22	0	0	2SF1045
23	0	0	2SF1050
24	0	0	2SF1055
25	0	0	2SF1100

Table 2b - Test #2, location 2, smoke-free entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	3SF900
2	0	0	3SF905
3	0	0	3SF910
4	0	0	3SF915
5	0	0	3SF920
6	0	0	3SF925
7	0	0	3SF930
8	0	0	3SF935
9	0	0	3SF940
10	0	0	3SF945
11	0	0	3SF950
12	0	0	3SF955
13	0	0	3SF1000
14	0	0	3SF1005
15	0	0	3SF1010
16	0	0	3SF1015
17	.17	.003	3SF1020
18	.17	.003	3SF1025
19	.19	.003	3SF1030
20	.09	.001	3SF1035
21	.26	.004	3SF1040
22	.26	.004	3SF1045
23	.24	.004	3SF1050
24	.19	.003	3SF1055
25	.12	.002	3SF1100

Table 2c - Test #2, location 3, smoke-free entry

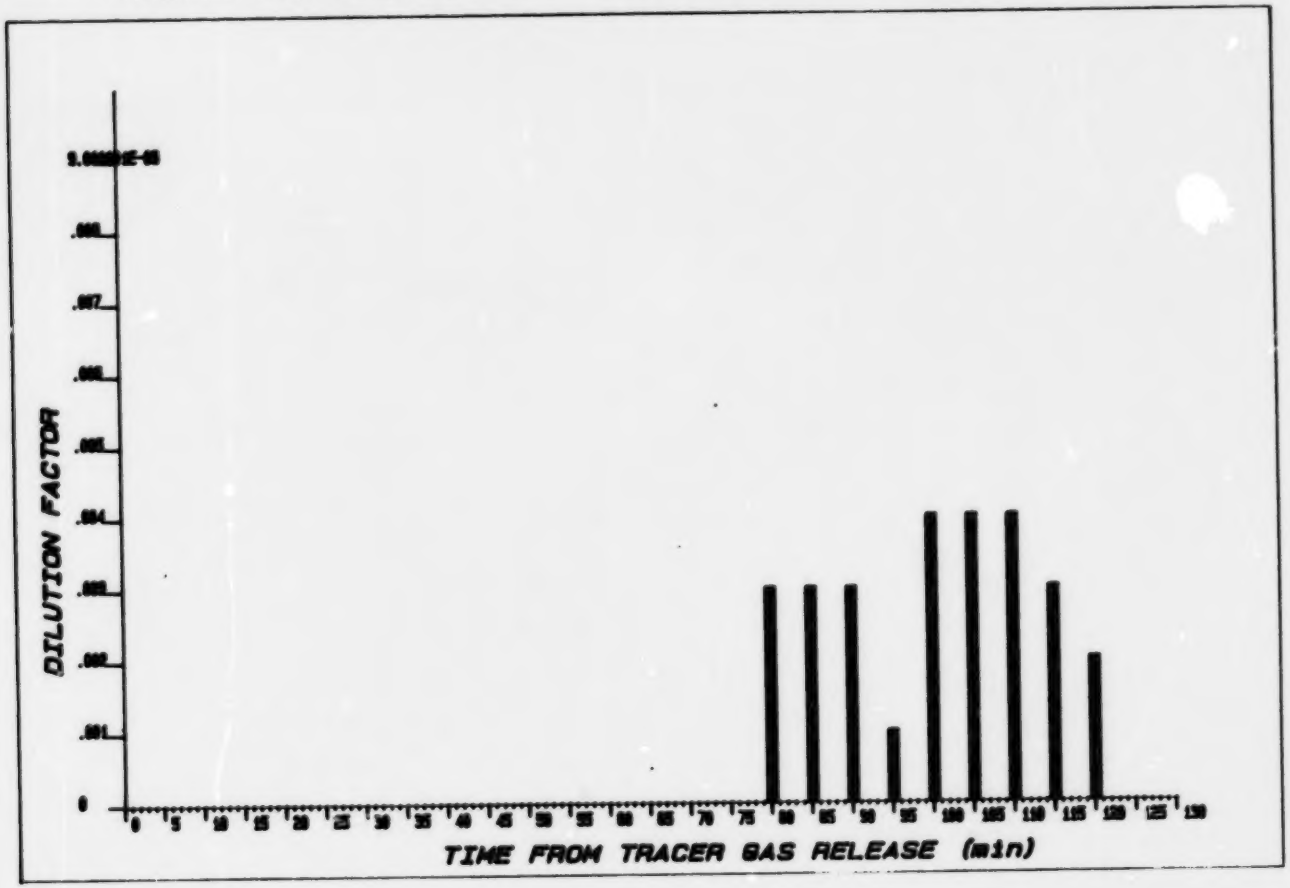

Figure 3a - Test #2, smoke-free entry - location 3

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	48.43	.874	1D917
2	51.79	.9340000000000001	1D931
3	53.72	.969	1D946
4	54.84	.989	1D1001
5	54.84	.989	1D1016
6	52.92	.955	1D1031
7	52.94	.955	1D1046
8	54.84	.989	1D1100

Table 3a - Test #2, location 1, diesel entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	2D902
2	33.57	.606	2D917
3	51.62	.931	2D932
4	52.52	.948	2D947
5	53.52	.966	2D1002
6	53.35	.963	2D1017
7	53.3	.962	2D1032
8	53.26	.961	2D1047
9	53.59	.967	2D1102

Table 3b - Test #2, location 2, diesel entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	3D902
2	0	0	3D908
3	17.94	.323	3D927
4	39.97	.721	3D943
5	43.45	.784	3D957
6	46.39	.837	3D1012
7	45.85	.827	3D1027
8	48.55	.876	3D1045
9	48.9	.882	3D1057

Table 3c - Test #2, location 3, diesel entry

MPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	1B900
2	0	0	1B905
3	.53	8.999999999999999D-03	1B910
4	2.63	.047	1B915
5	5.62	.101	1B920
6	10.45	.188	1B925
7	13.22	.238	1B930
8	16.49	.297	1B935
9	17.1	.308	1B940
10	18.66	.336	1B945
11	22.49	.405	1B950
12	19.91	.359	1B955
13	20.8	.375	1B1000
14	21.89	.395	1B1005
15	22.46	.405	1B1010
16	22.79	.411	1B1015
17	21.28	.384	1B1020
18	21.14	.381	1B1025
19	23.71	.428	1B1030
20	22.16	.4	1B1035
21	22.41	.404	1B1040
22	22.13	.399	1B1045
23	22.99	.415	1B1050
24	22.74	.41	1B1055
25	22.12	.399	1B1100

Table 4a - Test #2, location 1, belt entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	2B901
2	0	0	2B906
3	0	0	2B911
4	0	0	2B916
5	.68	.012	2B921
6	.8	.014	2B926
7	3.3	.059	2B931
8	6.35	.114	2B936
9	10.18	.183	2B941
10	14.02	.253	2B946
11	16.79	.303	2B951
12	19.85	.358	2B956
13	21.2	.382	2B1001
14	22.3	.402	2B1006
15	23.43	.422	2B1011
16	24.14	.435	2B1016
17	24.33	.439	2B1021
18	24.4	.44	2B1026
19	24.93	.45	2B1031
20	25.22	.455	2B1036
21	25.58	.461	2B1041
22	25.58	.461	2B1046
23	25.66	.463	2B1051
24	26.08	.47	2B1056
25	25.37	.457	2B1101

Table 4b - Test #2, location 2, belt entry

SAMPLE #	CONCENTRATION(ppb)	DILUTION RATIO	SAMPLE ID
1	0	0	3B901
2	0	0	3B906
3	0	0	3B911
4	0	0	3B916
5	0	0	3B921
6	0	0	3B926
7	.19	.003	3B931
8	.73	.013	3B936
9	1.75	.031	3B941
10	4.05	.073	3B946
11	7.15	.129	3B951
12	9.99	.18	3B956
13	13.73	.247	3B1001
14	16.83	.303	3B1006
15	19.03	.343	3B1011
16	21.13	.381	3B1016
17	22.24	.401	3B1021
18	23.49	.424	3B1026
19	24.31	.438	3B1031
20	24.73	.446	3B1036
21	25.22	.455	3B1041
22	25.69	.463	3B1046
23	25.86	.466	3B1051
24	25.98	.468	3B1055
25	25.85	.466	3B1059

Table 4c - Test #2, location 3, belt entry

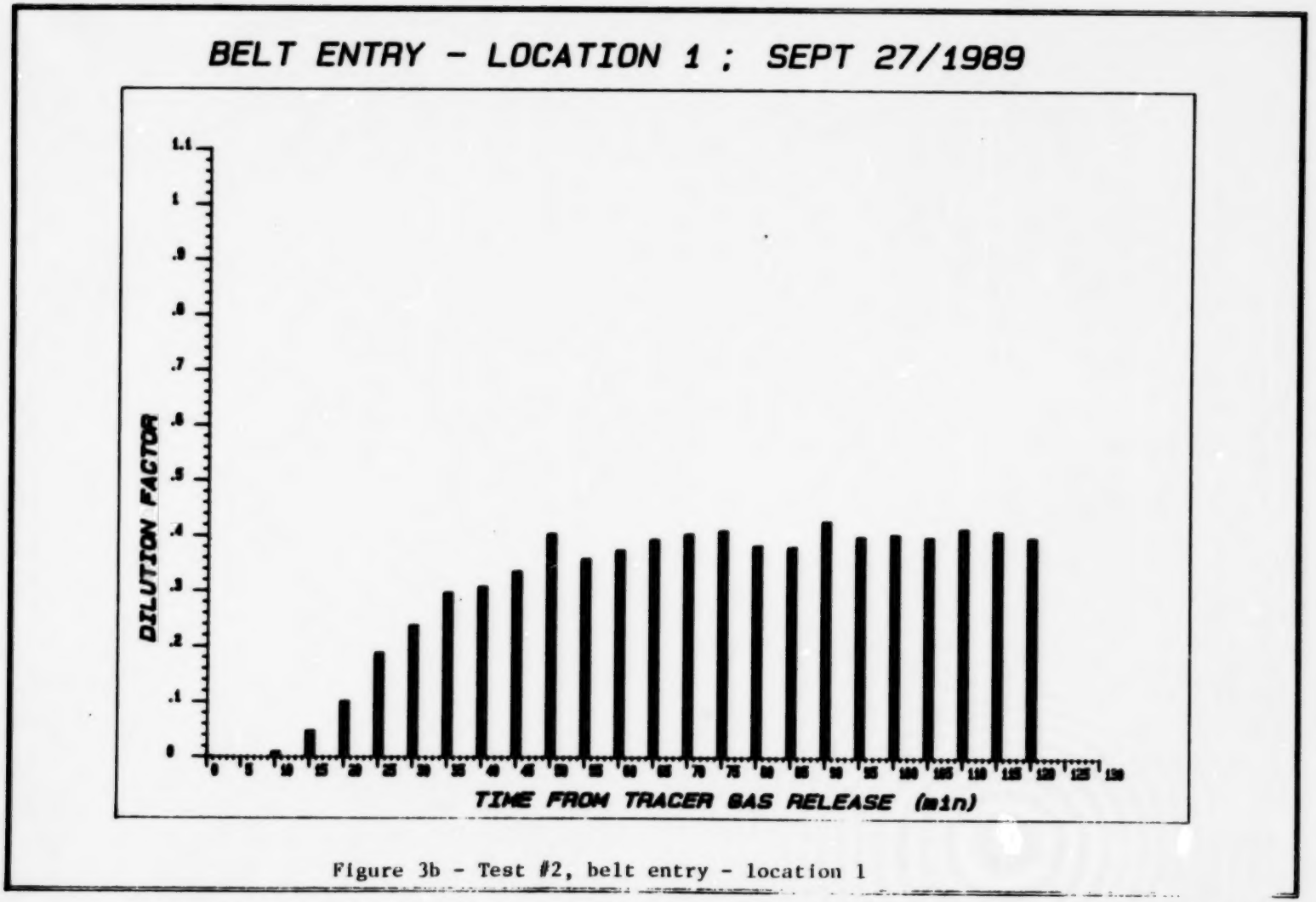

Figure 3b - Test #2, belt entry - location 1

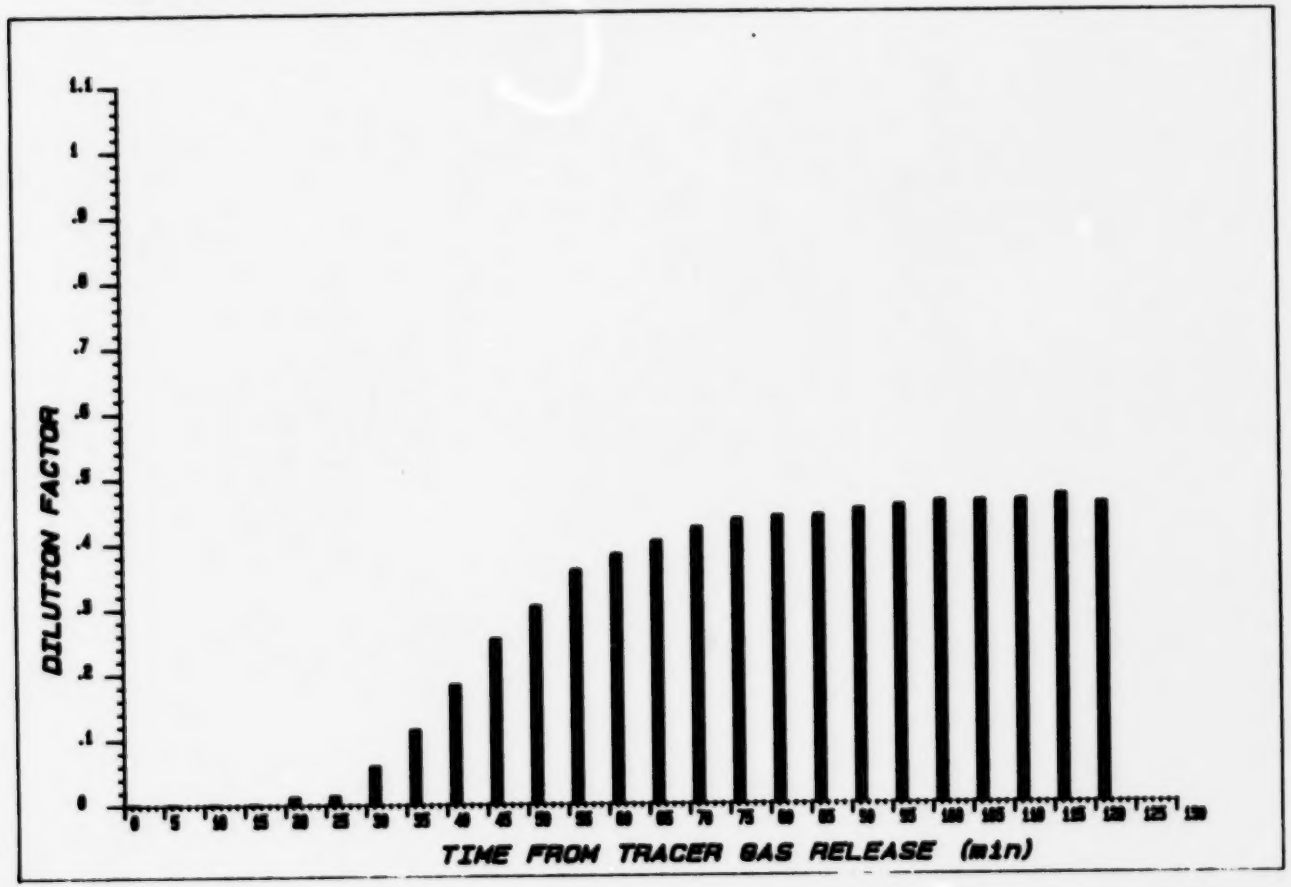

Figure 3c - Test #2, belt entry - location 2

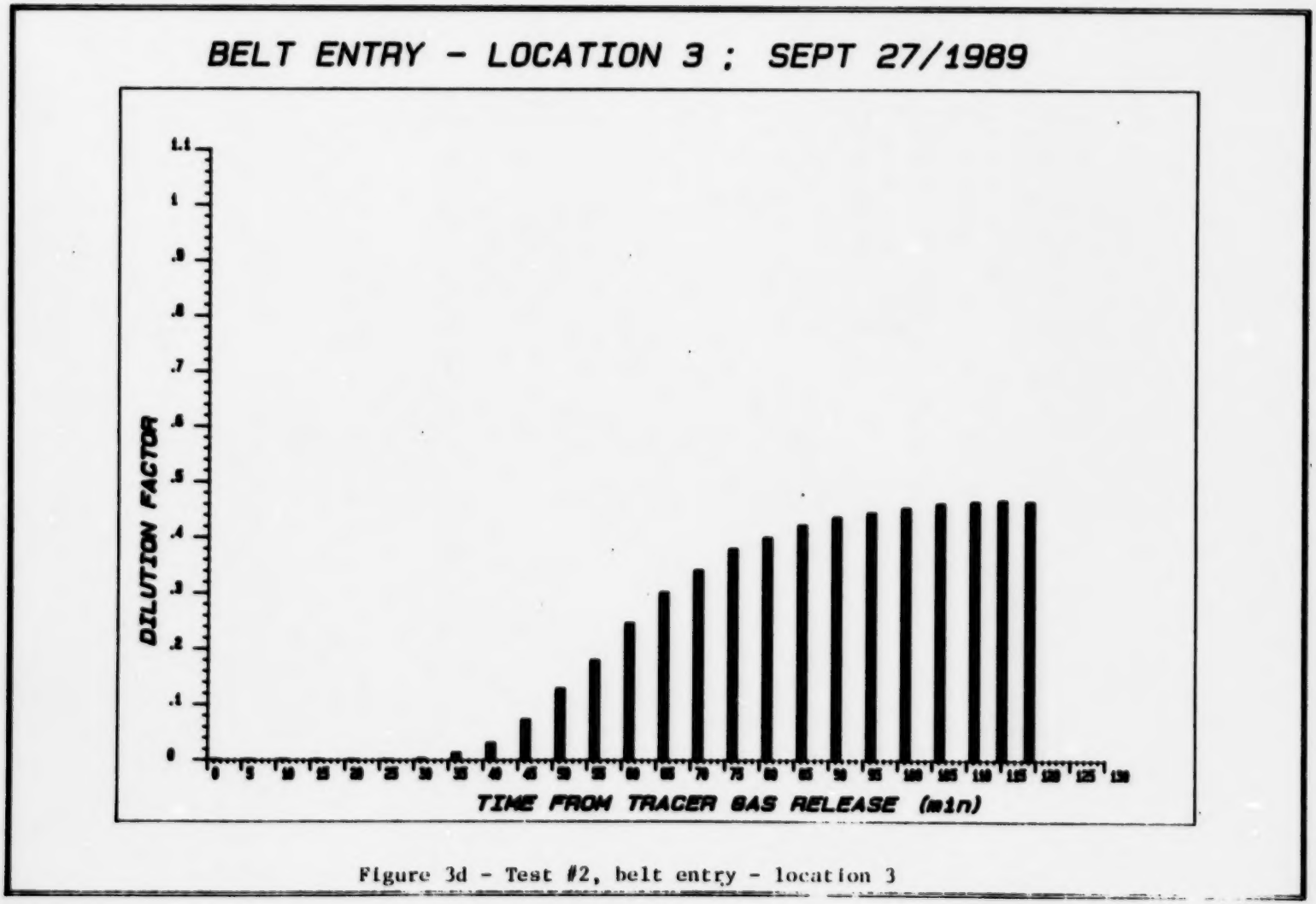

Figure 3d - Test #2, belt entry - location 3

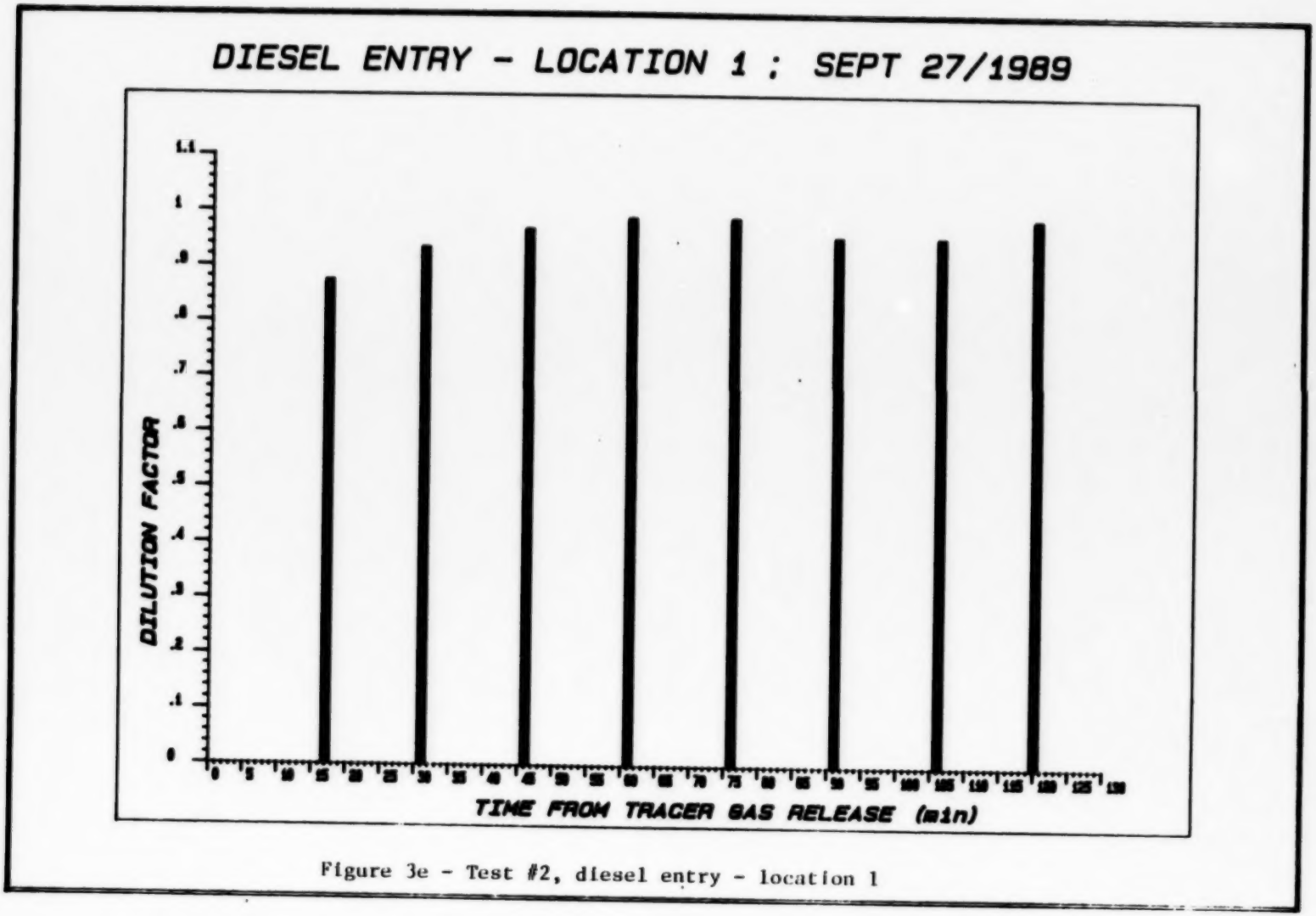

Figure 3e - Test #2, diesel entry - location 1

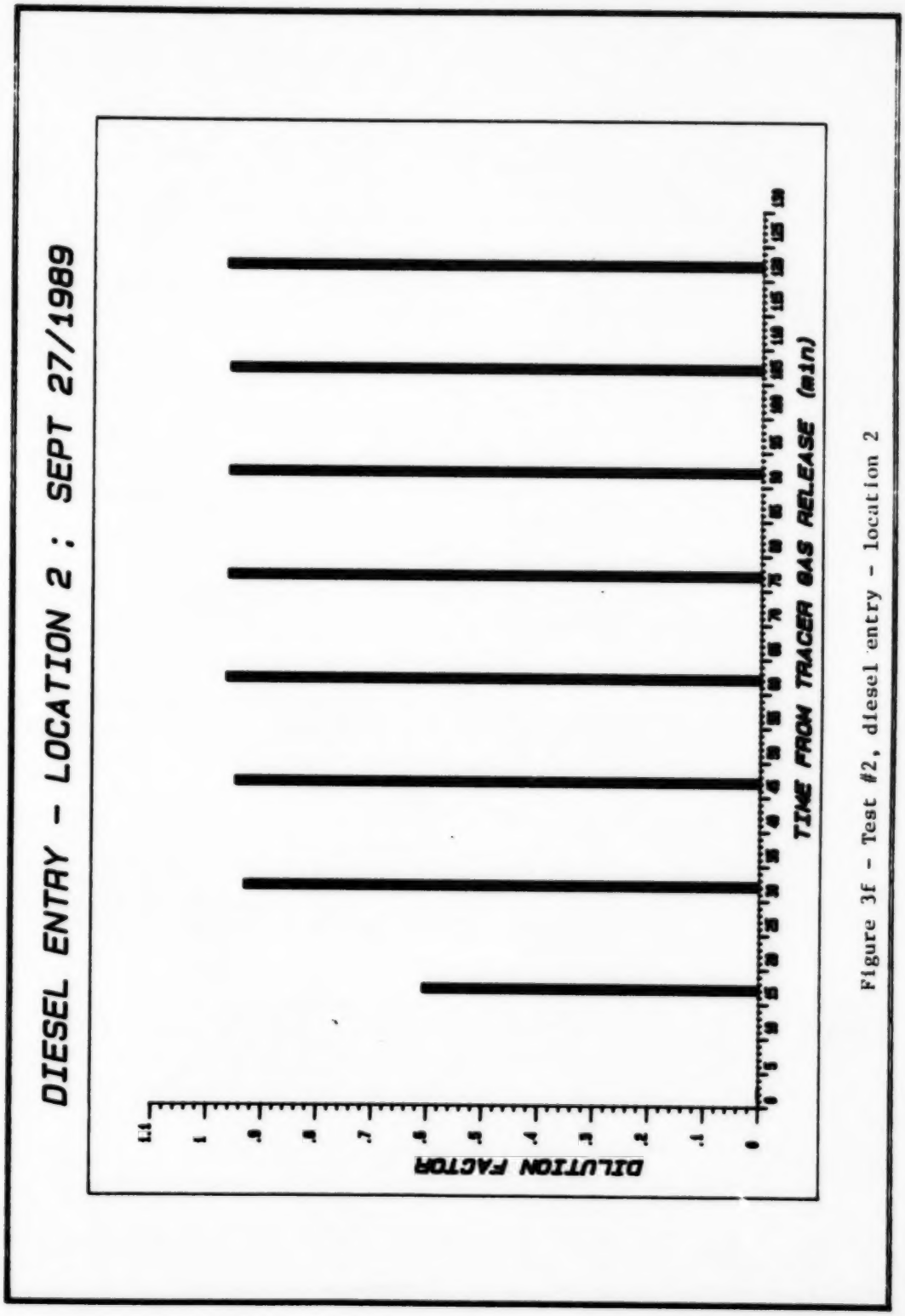

Figure 3f - Test #2, diesel entry - location 2

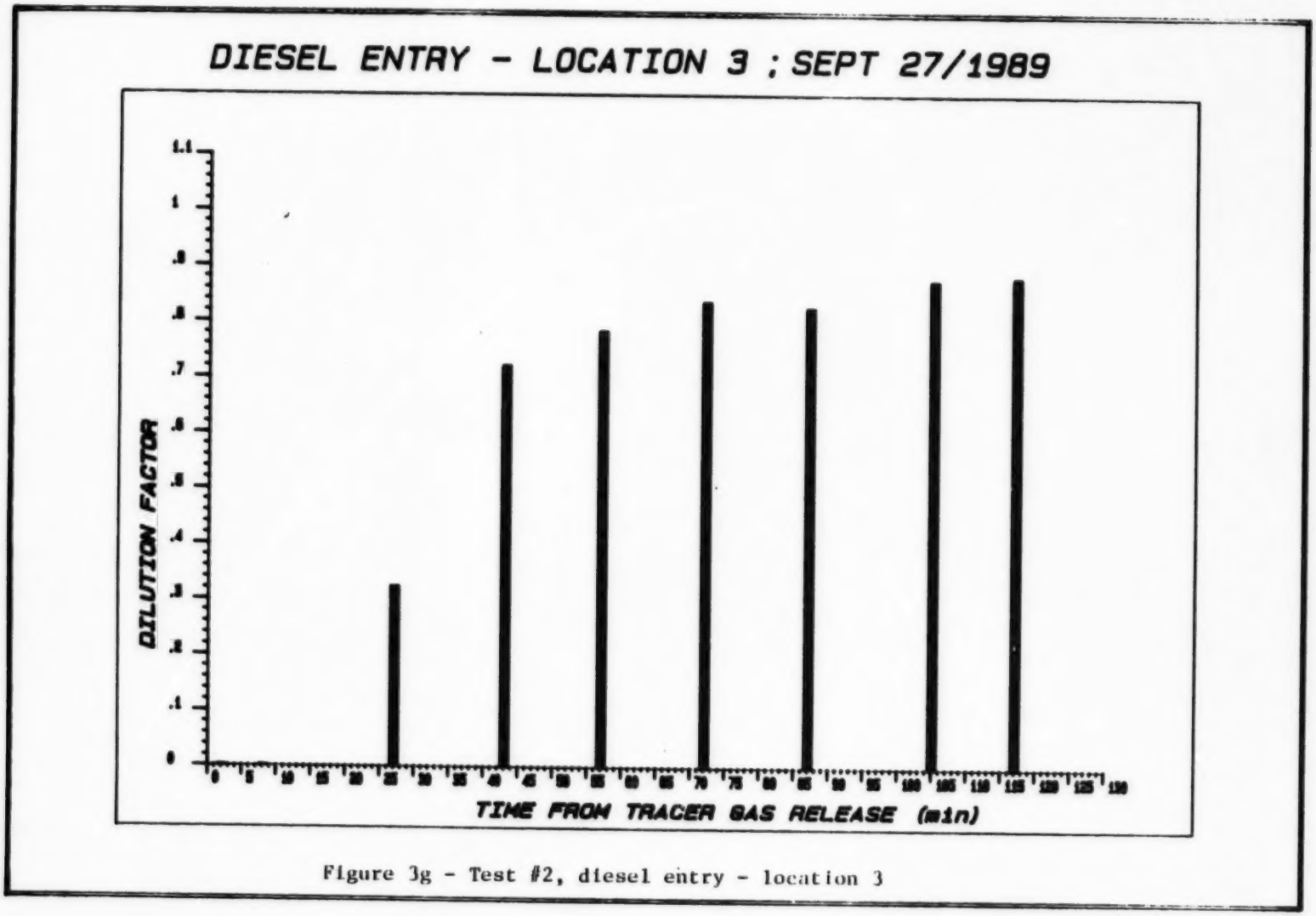

Figure 3g - Test #2, diesel entry - location 3